Lake Michigan: State of the Lake Conference
Sept 26-28, 2011 Michigan City, Indiana

# Post-Audit of Lake Michigan Lake Trout PCB Forecasts

## Lake Michigan Mass Balance Study

R.G. Kreis, Jr.[1], Xiaomi Zhang[2],
E. Murphy[3], K.R. Rygwelski[1],
G. Warren[3], P.J. Horvatin[3], W. Melendez[4],
S.J. Beck[3], and T.M. Holsen[5]

[1] U.S. EPA/ORD/NHEERL/MED – Grosse Ile, Michigan
[2] Z-Tech Corporation, LLC. – Grosse Ile, Michigan
[3] U.S. EPA Great Lakes National Program Office – Chicago, Illinois
[4] Computer Sciences Corporation – Grosse Ile, Michigan
[5]Clarkson University – Potsdam, New York

# Lake Michigan Mass Balance Study: Cooperators

Federal

USEPA: GLNPO, ORD, OAR, OW, Regions 2 and 5

USGS: Middleton, Madison, Ann Arbor; NOAA-GLERL

USFWS: Green Bay;  USDOE; Environment Canada

State

ILDNR, INDEM, MIDEQ, MDNR, WIDNR,

WI State Lab of Hygiene, Illinois Water Survey

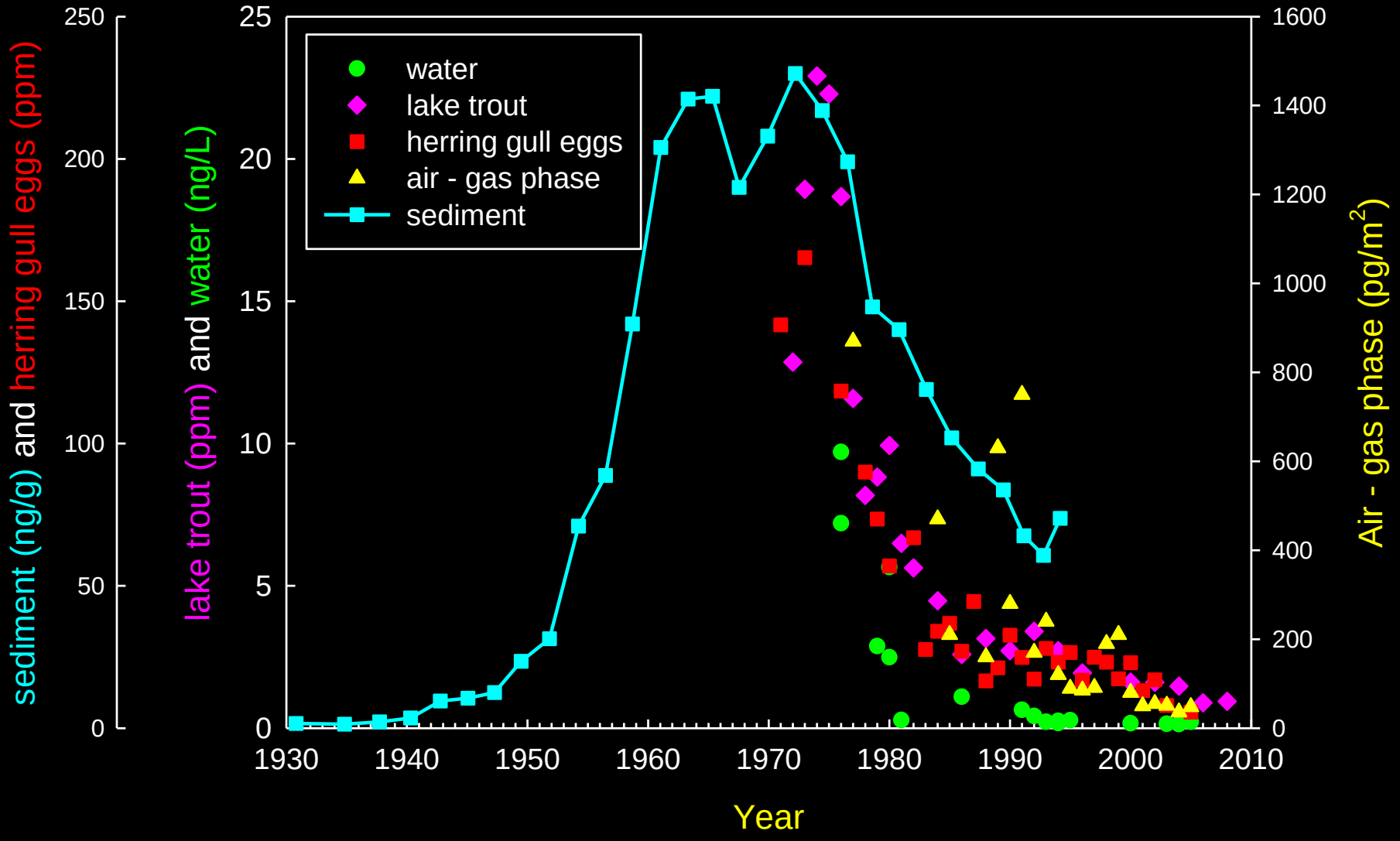
Academic

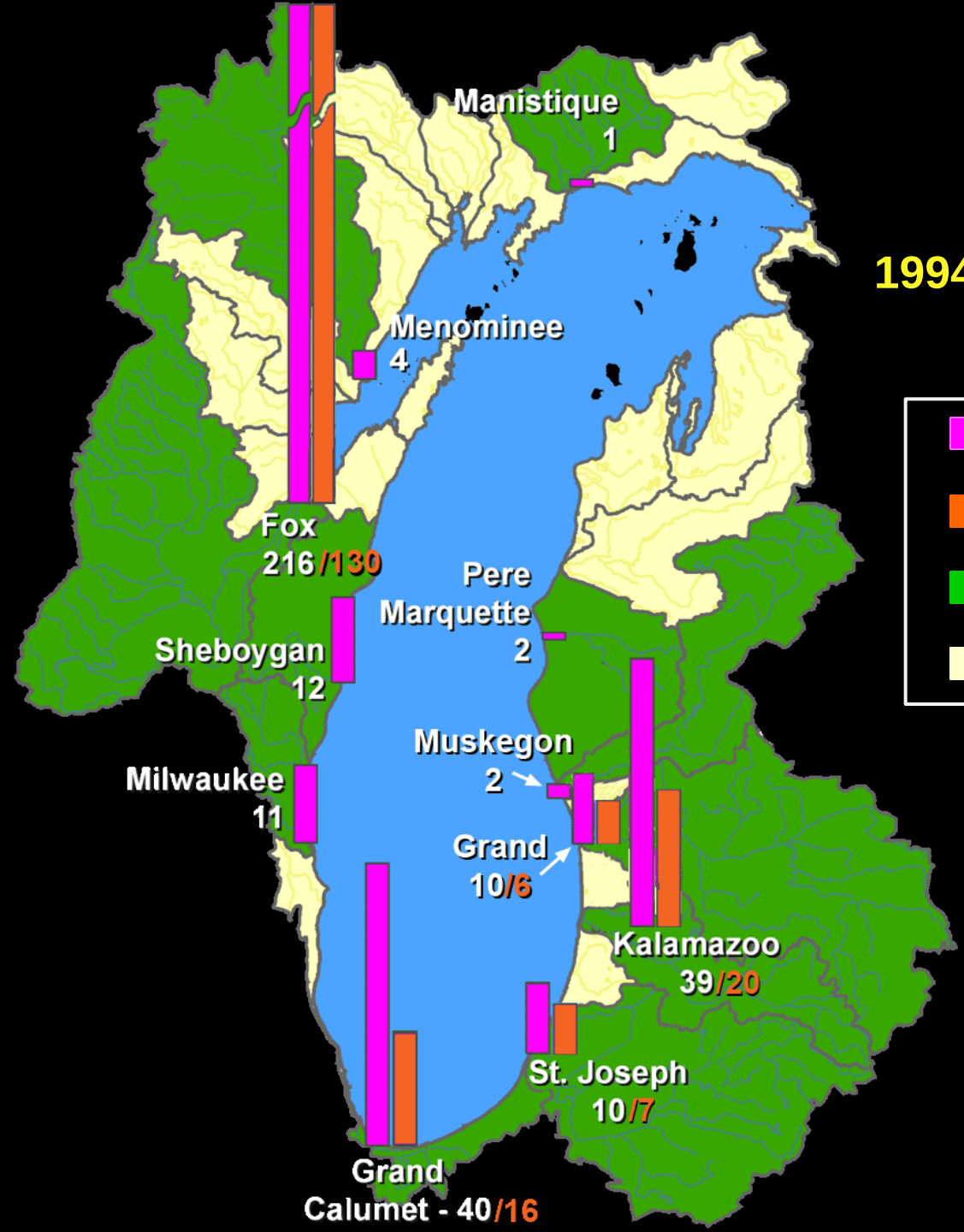
Clarkson Univ; Indiana Univ; Rutgers Univ; Univ. Iowa;

Univ Maryland; Univ Michigan; Univ Minnesota;

Univ Wisconsin

# Total PCB Trends in Lake Michigan Media






# Average PCB Tributary Loads

## 1994-1995 and 2005-2006 (kg/year)

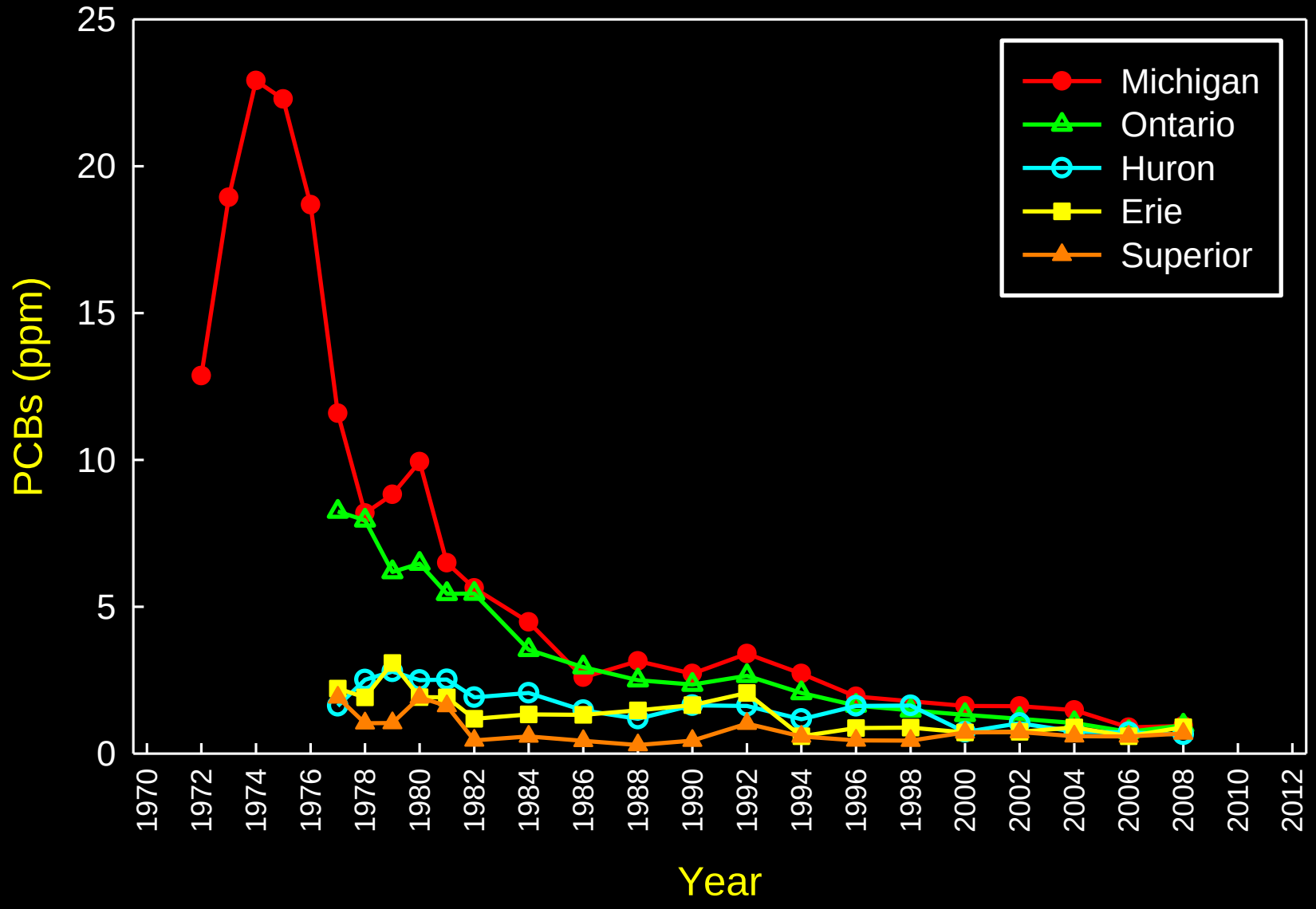
- PCB loads 1994-1995
- PCB loads 2005-2006
- Monitored tributary loads: 347 kg/year
- Unmonitored tributary loads: 31 kg/year

# Program and Action Accountability and Reporting

- PCB Production Ban (1977)
- Waukegan Sediment Removal
- Superfund Sediment Removal
- Binational Toxics Strategy
- Fox River Sediment Removal
- Great Lakes Legacy Act
- Great Lakes Restoration Initiative
- Lake Michigan Lakewide Management Plan
- Great Lakes Water Quality Agreement
- Land-based Cleanups and Incineration Activities

# Total PCBs in Great Lakes Top Predator Fish, Even Year

## Lake Trout (Walleye in Lake Erie)



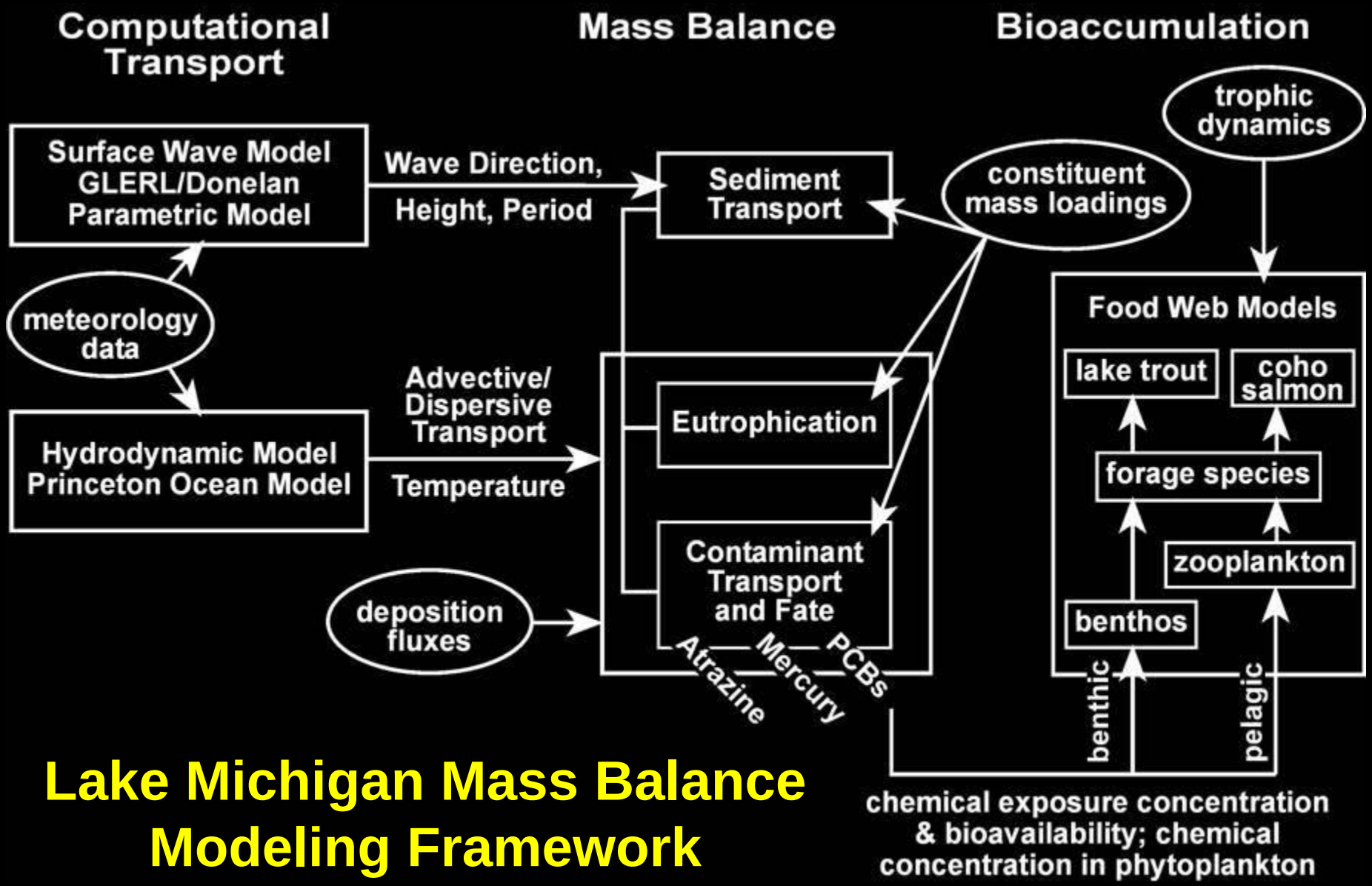
# Lake Michigan Consumption Guidelines

**(Excerpted and Adopted from the Mich. Dept. Comm. Health 2010)**

**- 13 Lake Michigan fish species have Consumption Advisories**
**- All have restricted consumption due to PCBs;**
**5 additionally due to Chlordane, DDT, Dioxin, and/or Mercury**

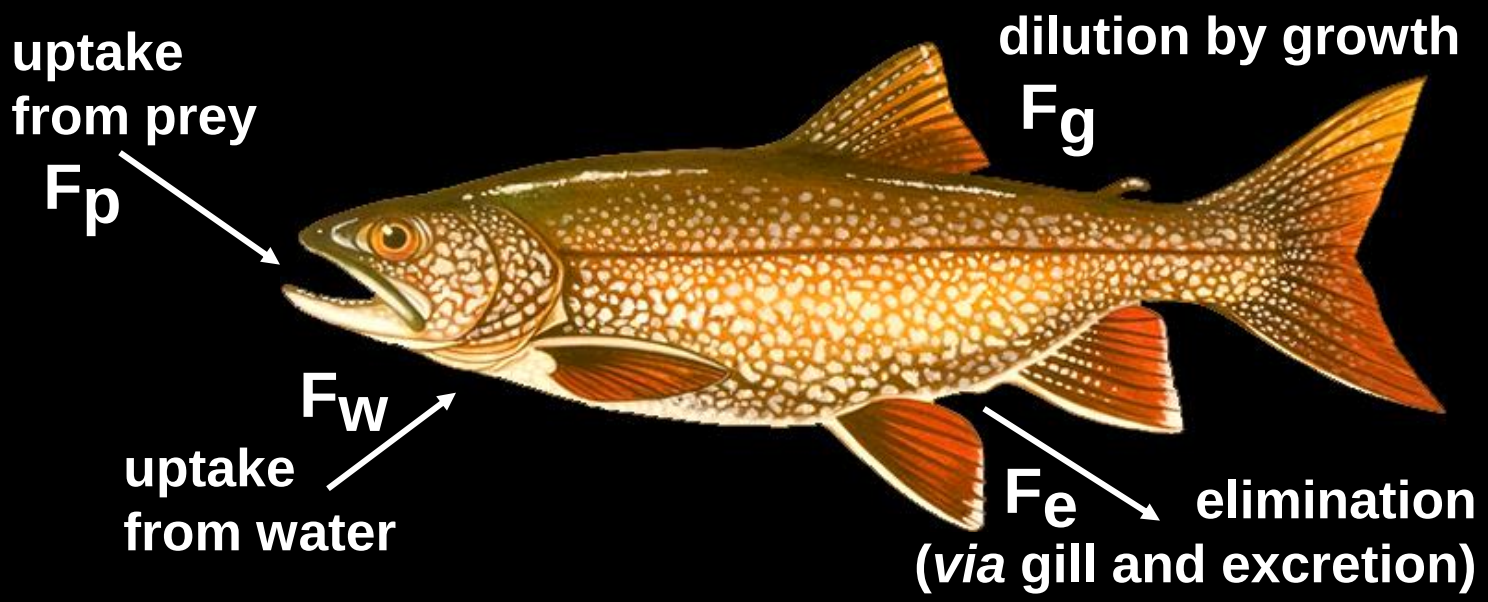
| | General Population | Women and Children |
|---|---|---|
| Lake Trout | | |
| 18-22 Inches | One Meal per Week | One Meal per Month |
| 22-26 Inches | Do Not Eat | Do Not Eat |
| 26-30 Inches | Do Not Eat | Do Not Eat |
| 30+ Inches | Do Not Eat | Do Not Eat |

*



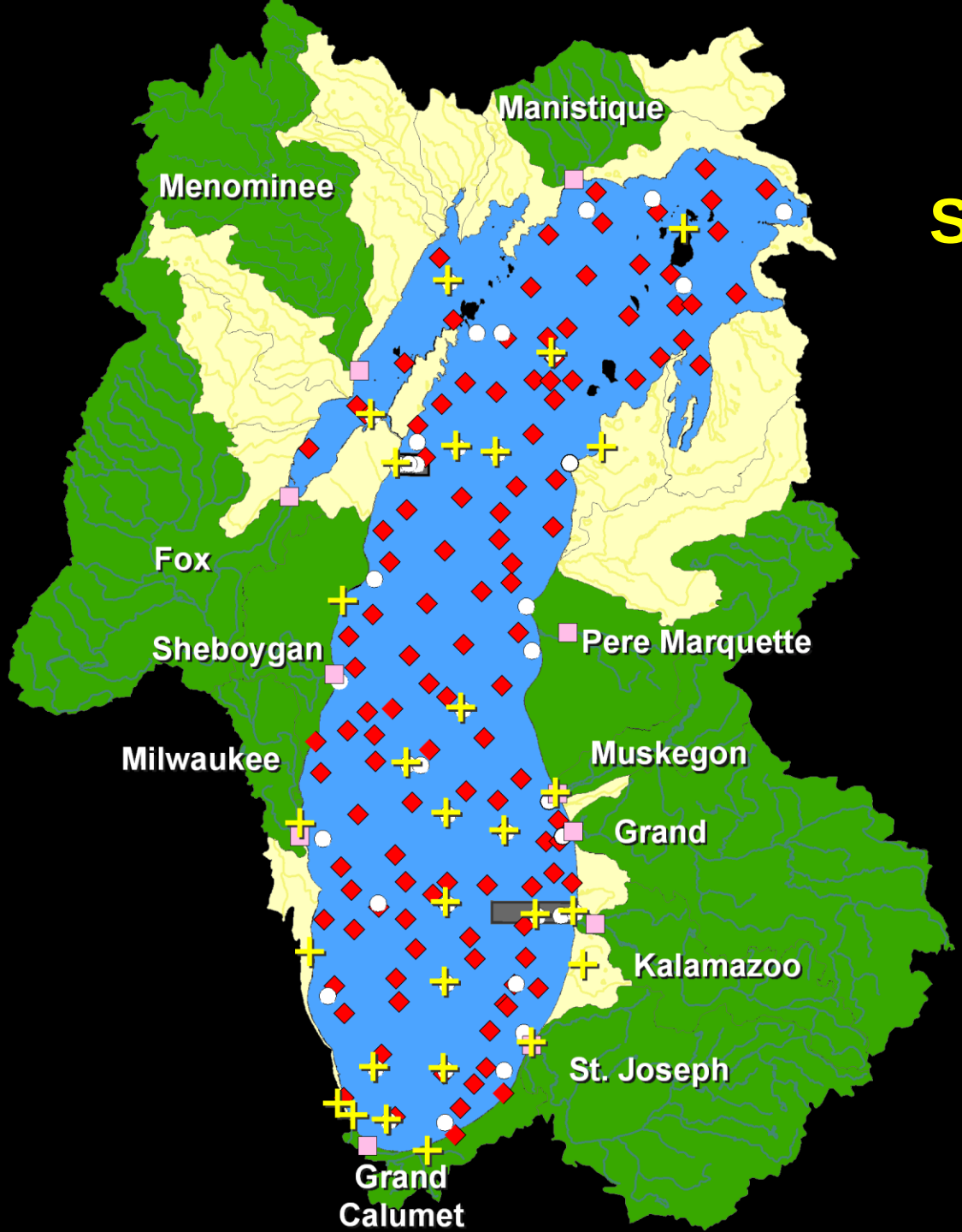

# Lake Michigan Mass Balance Modeling Framework

# Example Fish Mass Balance




Rate of Concentration Change = uptake from water + uptake from prey – elimination – growth

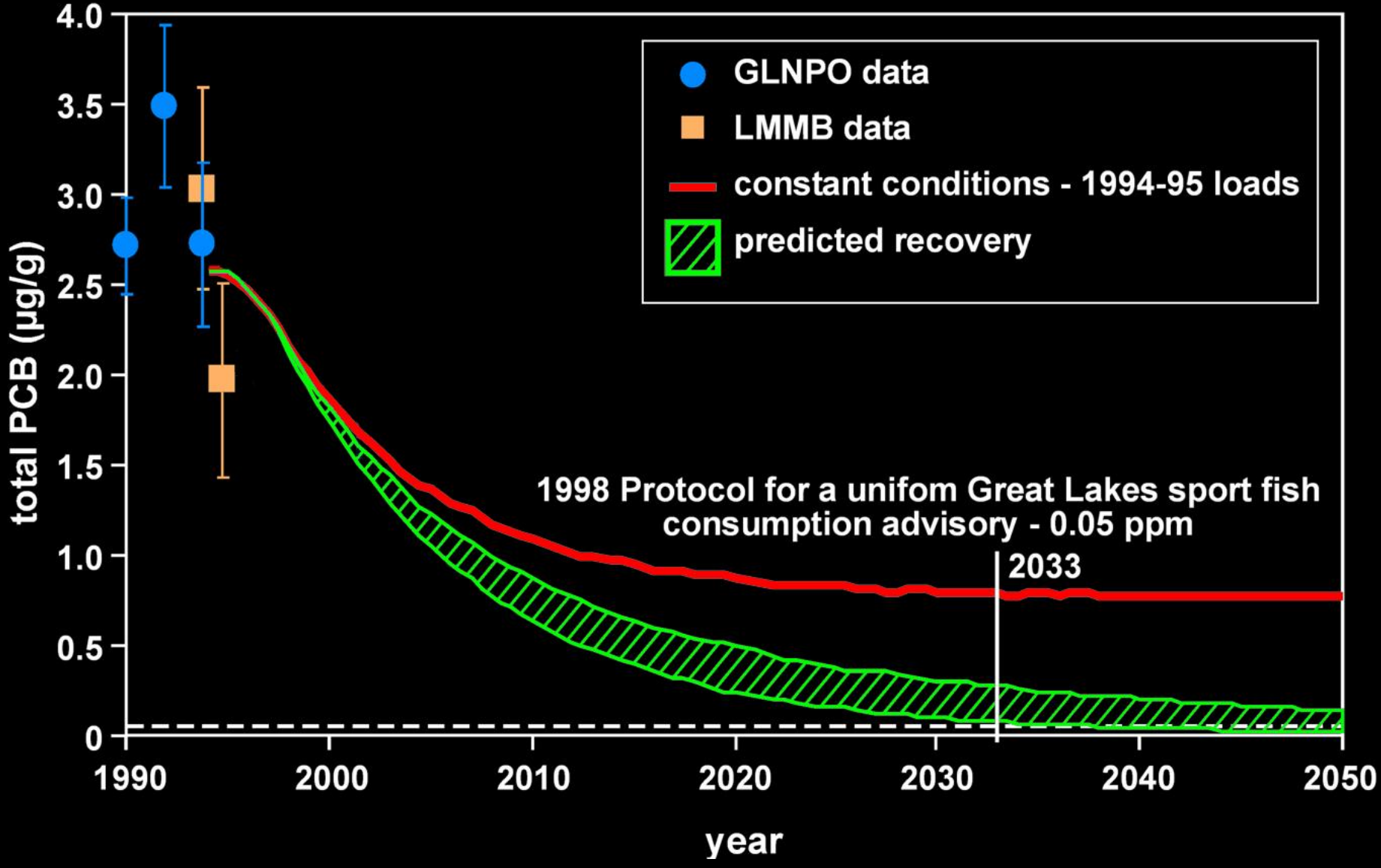
$$\frac{dC_f}{dt} = F_w + F_p - F_e - F_g$$



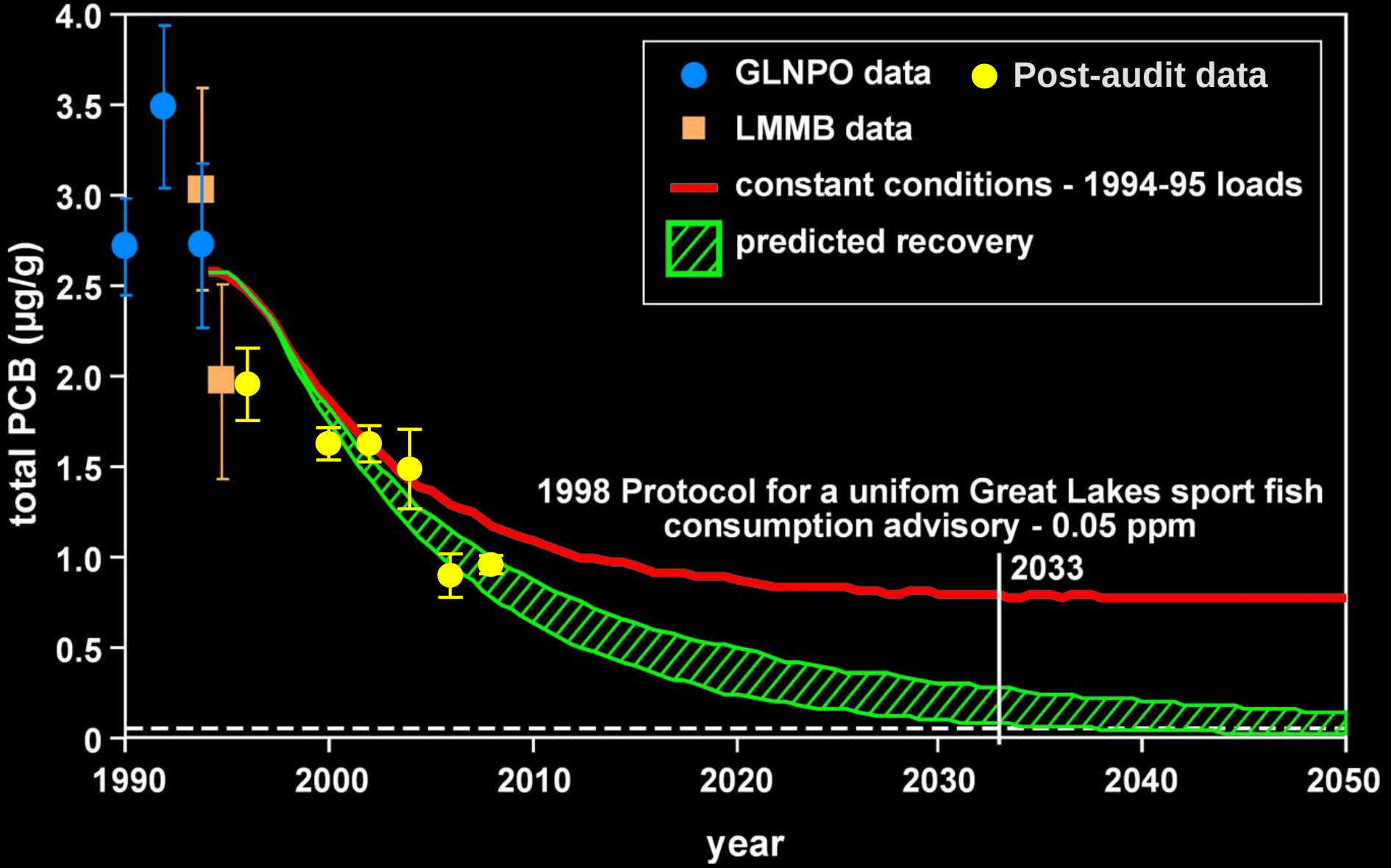

# Lake Michigan Sampling Design

- atmospheric monitoring stations
- sediment samples
- water survey stations
- tributary monitoring stations
- unmonitored tributary basins
- monitored tributary basins
- biota survey boxes

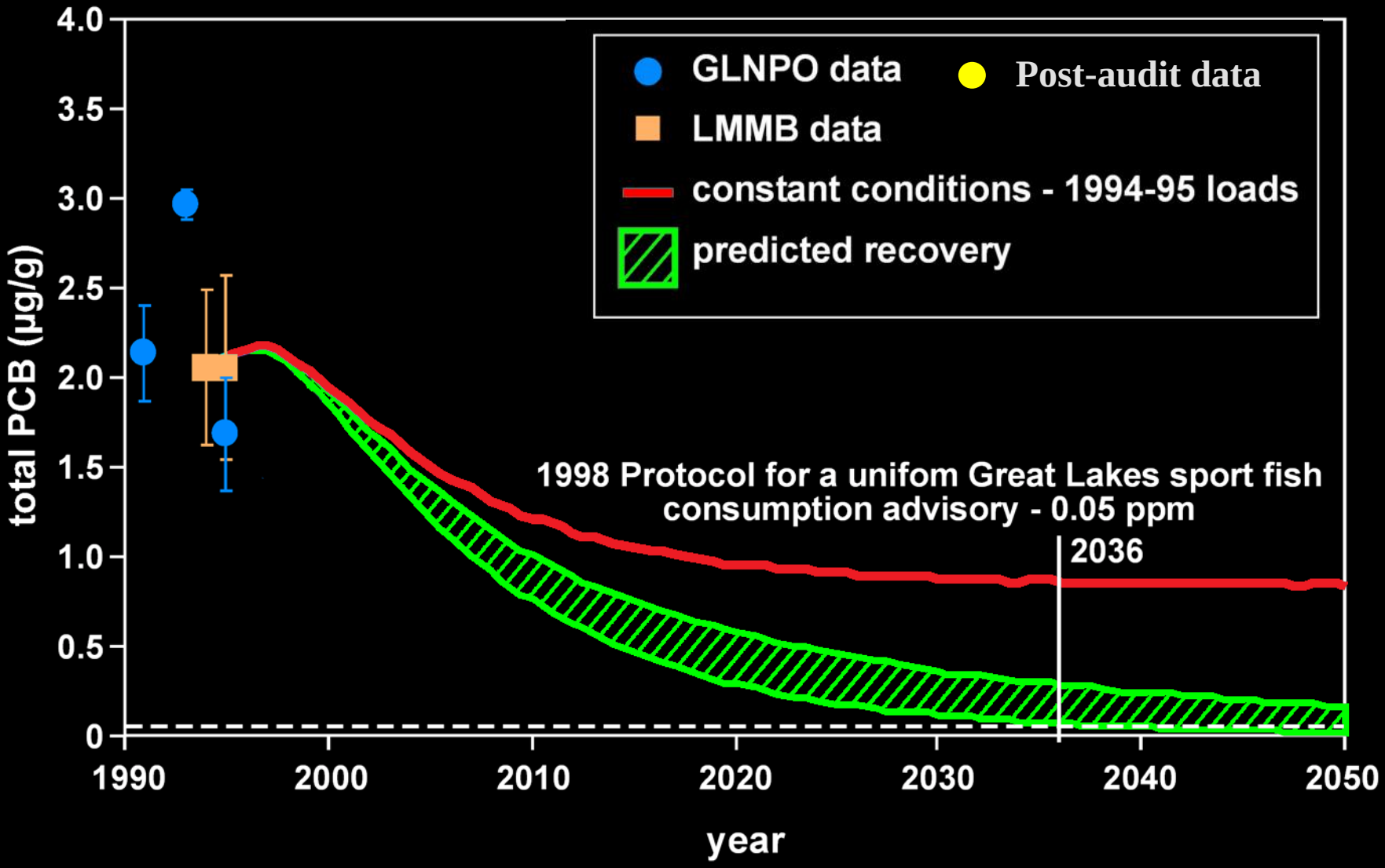
# Predicted PCB Concentrations in Age 5.5 Lake Michigan Lake Trout at Saugatuck



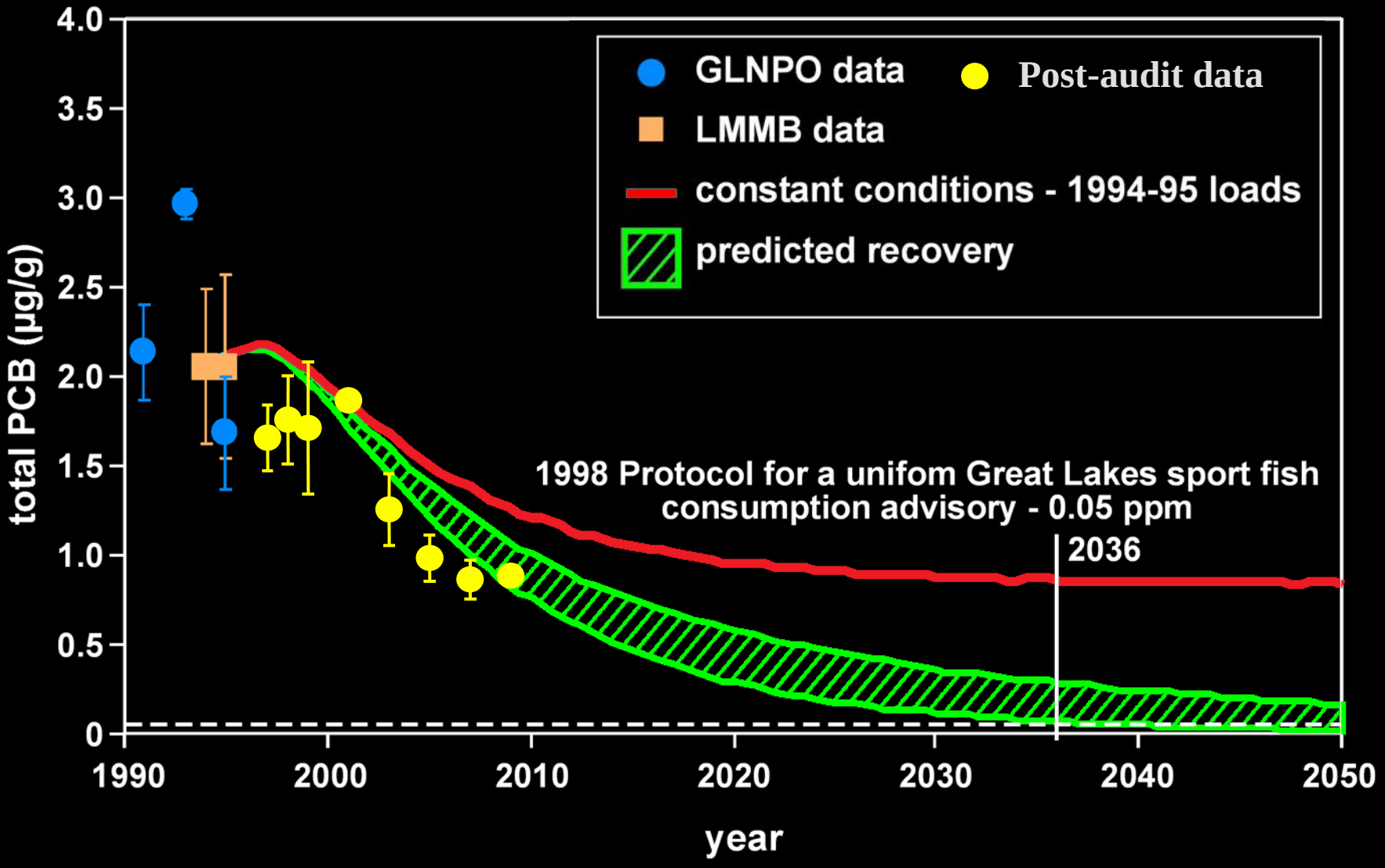
# PCB Forecasts and Post-Audit for Age 5.5 Lake Trout at Saugatuck



# Predicted PCB Concentrations in Age 5.5 Lake Michigan Lake Trout at Sturgeon Bay



# PCB Forecasts and Post-Audit of Age 5.5 Lake Trout at Sturgeon Bay



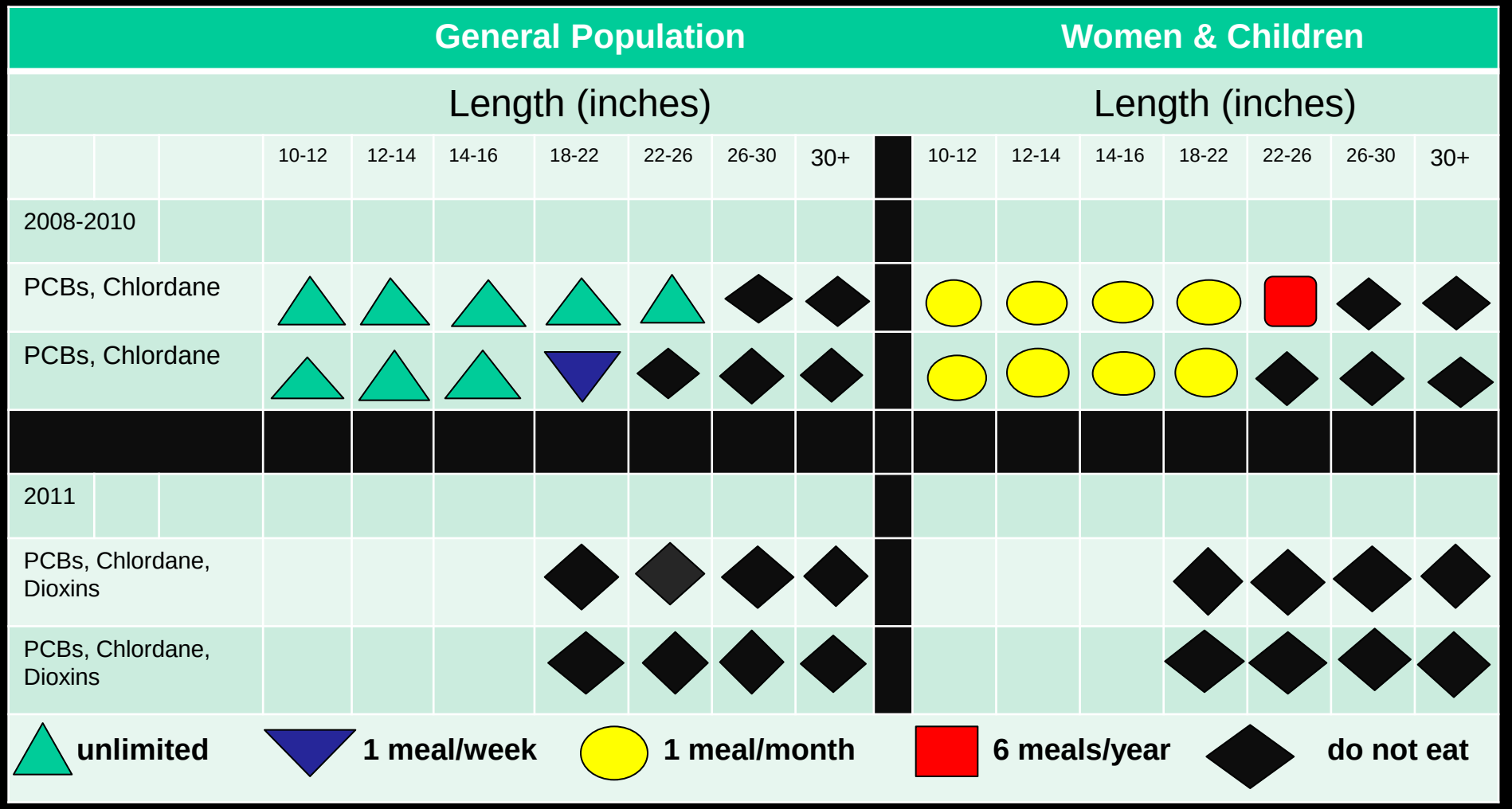
# Environmental Variability and Model Uncertainty

- Food Web Changes and Alterations
- Food Availability
- Water Levels and Temperature
- Future Load Decline Rates in Various Media, Particularly Vapor Phase Air Concentrations and Sediments
- Pace of Further Remedial Actions

# Major Findings

- Forecasted PCB concentrations in Lake Trout suggests Unlimited Consumption as early as 2033 and 2036 for Age 5-6 Lake Trout at Saugatuck and Sturgeon Bay, respectively *
- The approximate 15-year Post Audit indicates reasonable agreement between observed and forecasted concentrations
- PCB trends indicate that concentrations are declining in all media
- Atmospheric Deposition is the major external source of PCBs to the lake followed by Tributaries
- Major fluxes of PCBs move in and out of the through dynamic interaction and media

# MDCH 2011 Lake Trout Advisory Update: Lake Michigan - North and South of Frankfort



# Lake Michigan Lake Trout Toxicity Equivalence Factor (TEF)

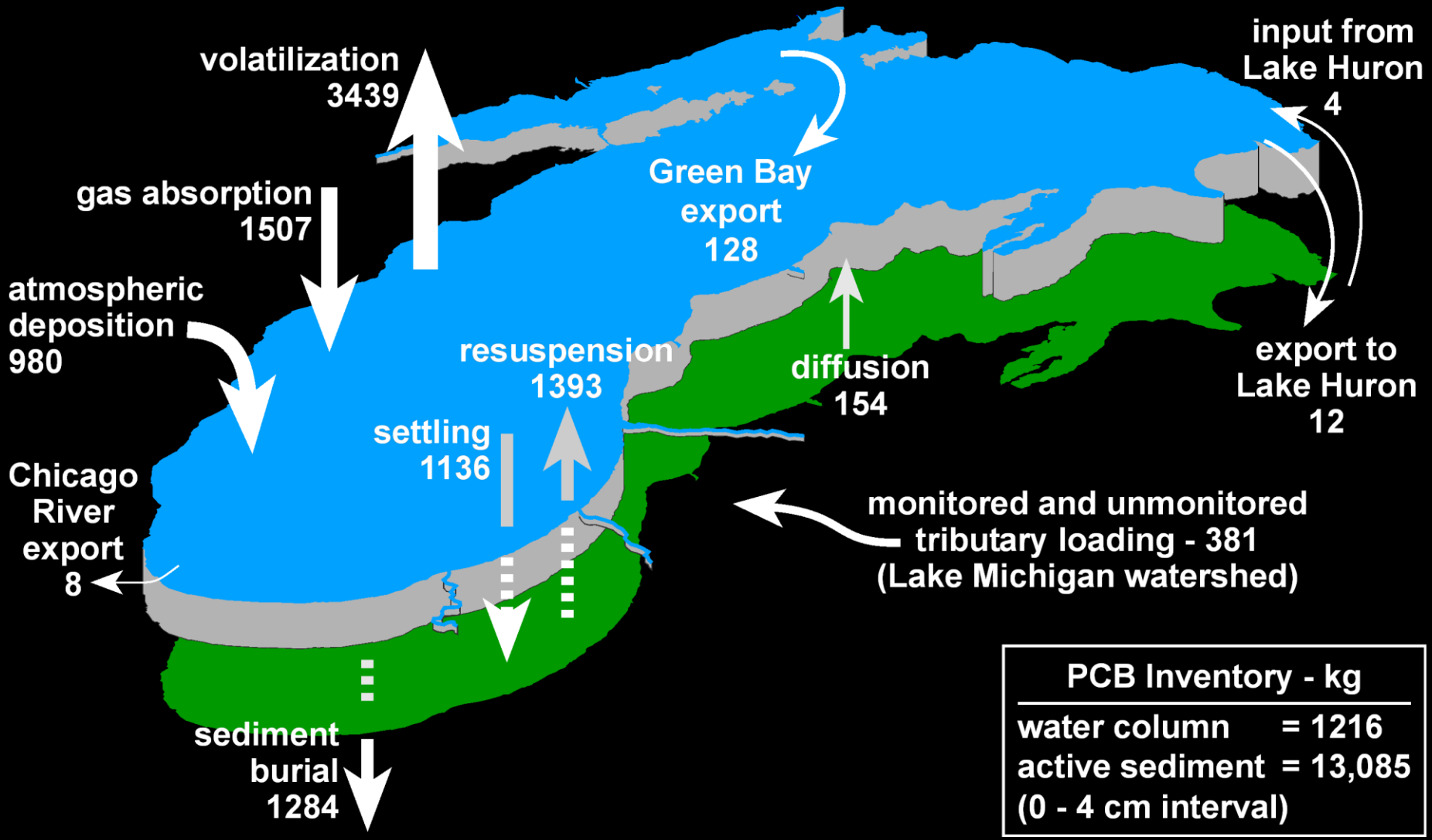
- Change in Methodology
- World Health Organization 2005; National Academy of Sciences 2006;  USEPA 2010
- Weighted, Additive Approach to Risk Assessment using Dioxin-like Compounds (Co-planar Congeners), Adjusted to the Toxicity Equivalent of 2,3,7,8-TCDD
- 7 Dioxins, 10 Furans, 12 PCBs
- Toxicity Predominantly from PCBs (greater than 80%)
- Lowered Threshold, but Greater Public Protection

# Management Implications

- The end of a 100-year PCB legacy appears to be within the foreseeable future
- Prevention of PCBs from entering the Lake is a top priority to curtail cycling and promote recovery
- PCB decline rates in Lake Trout can be accelerated by continuing a multi-pronged remedial approach to air, land, and watershed sources
- Remedial priorities based upon a quantifiable, scientific foundation for both local and lakewide perspectives should aid management decision-making
- Consistent and relaxed consumption advisories can provide ecosystem services with economic and social benefit

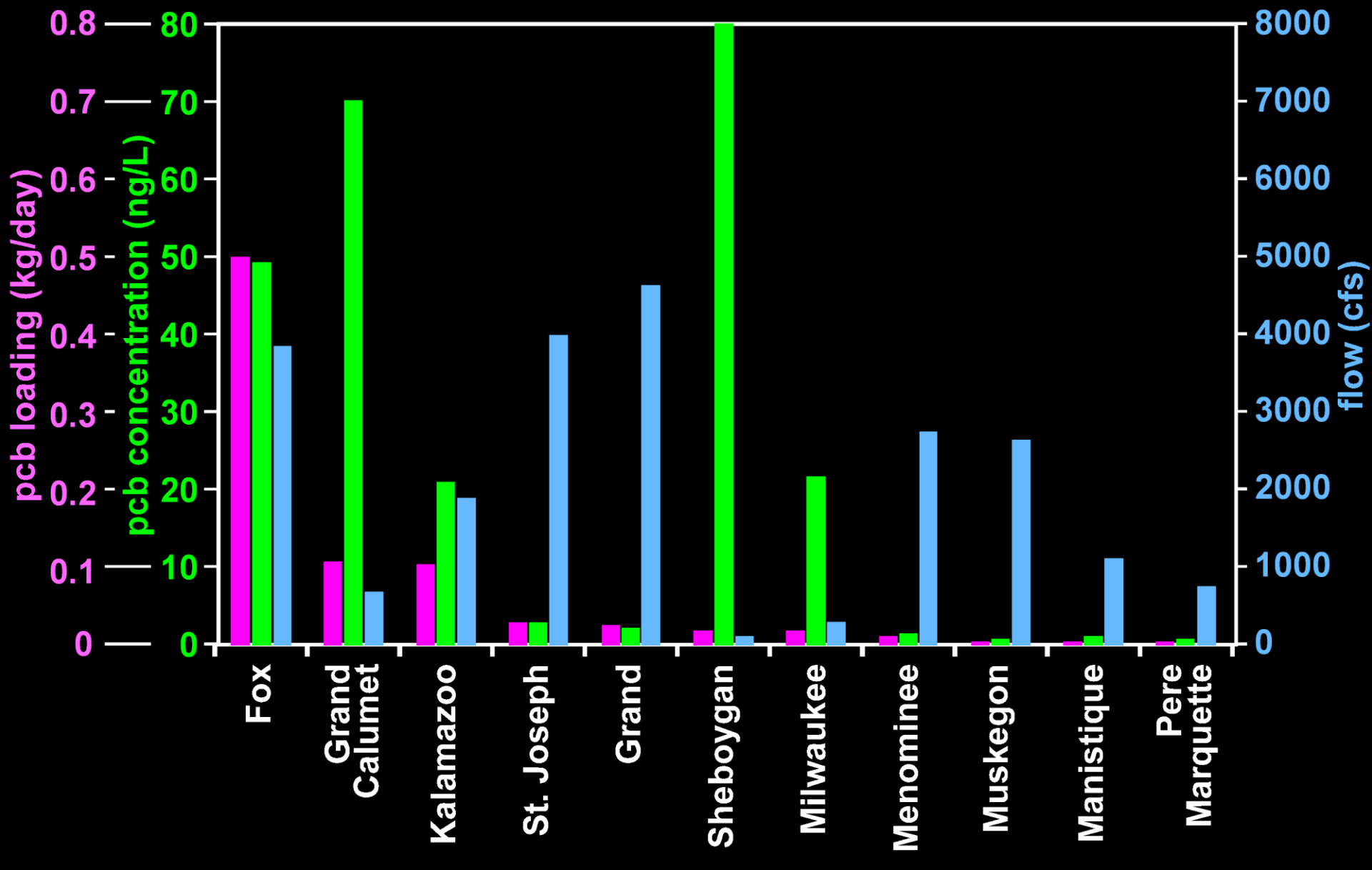
# Lake Michigan

# PCB Mass Balance (kg/yr) for 1994-1995

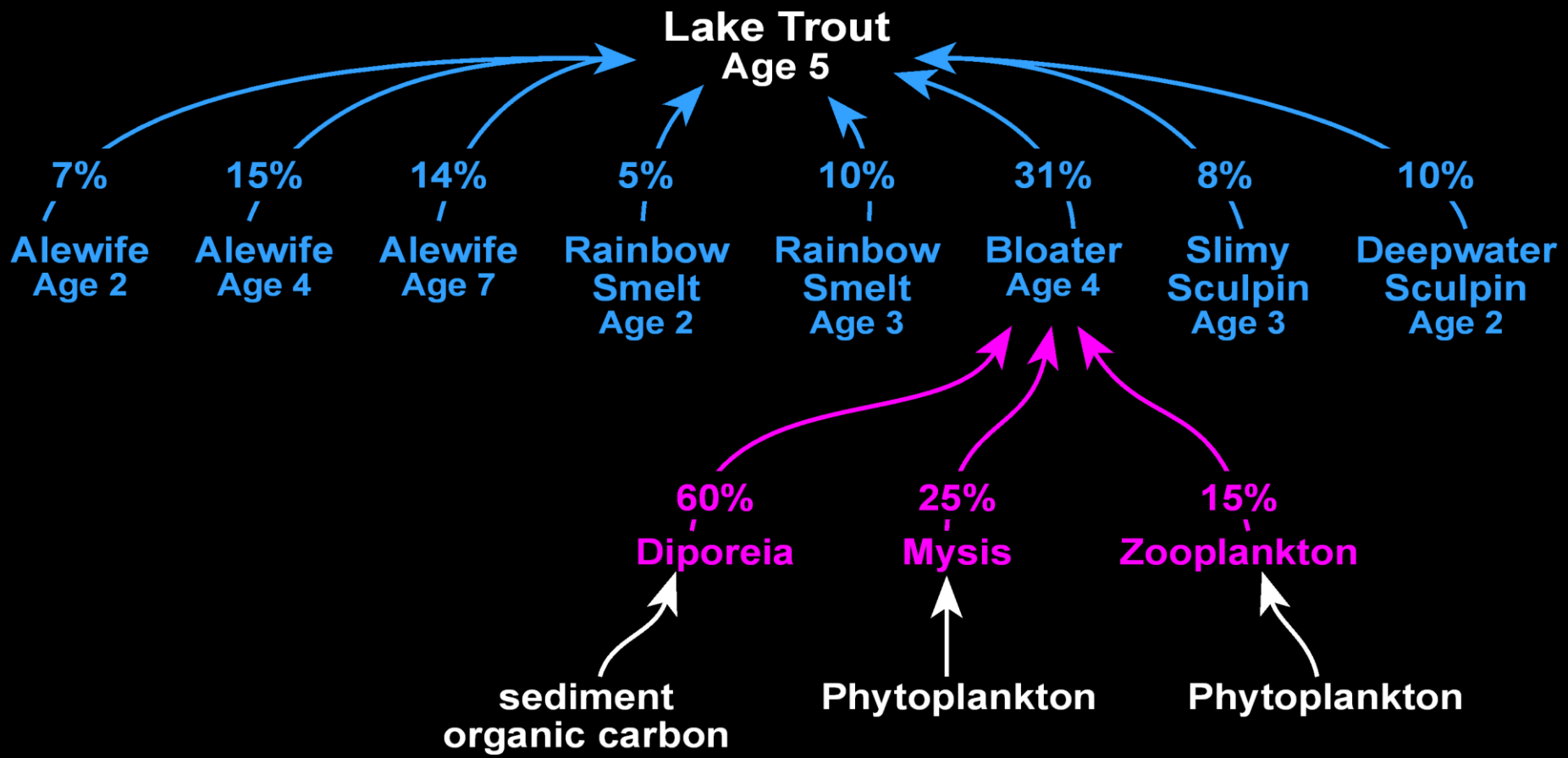


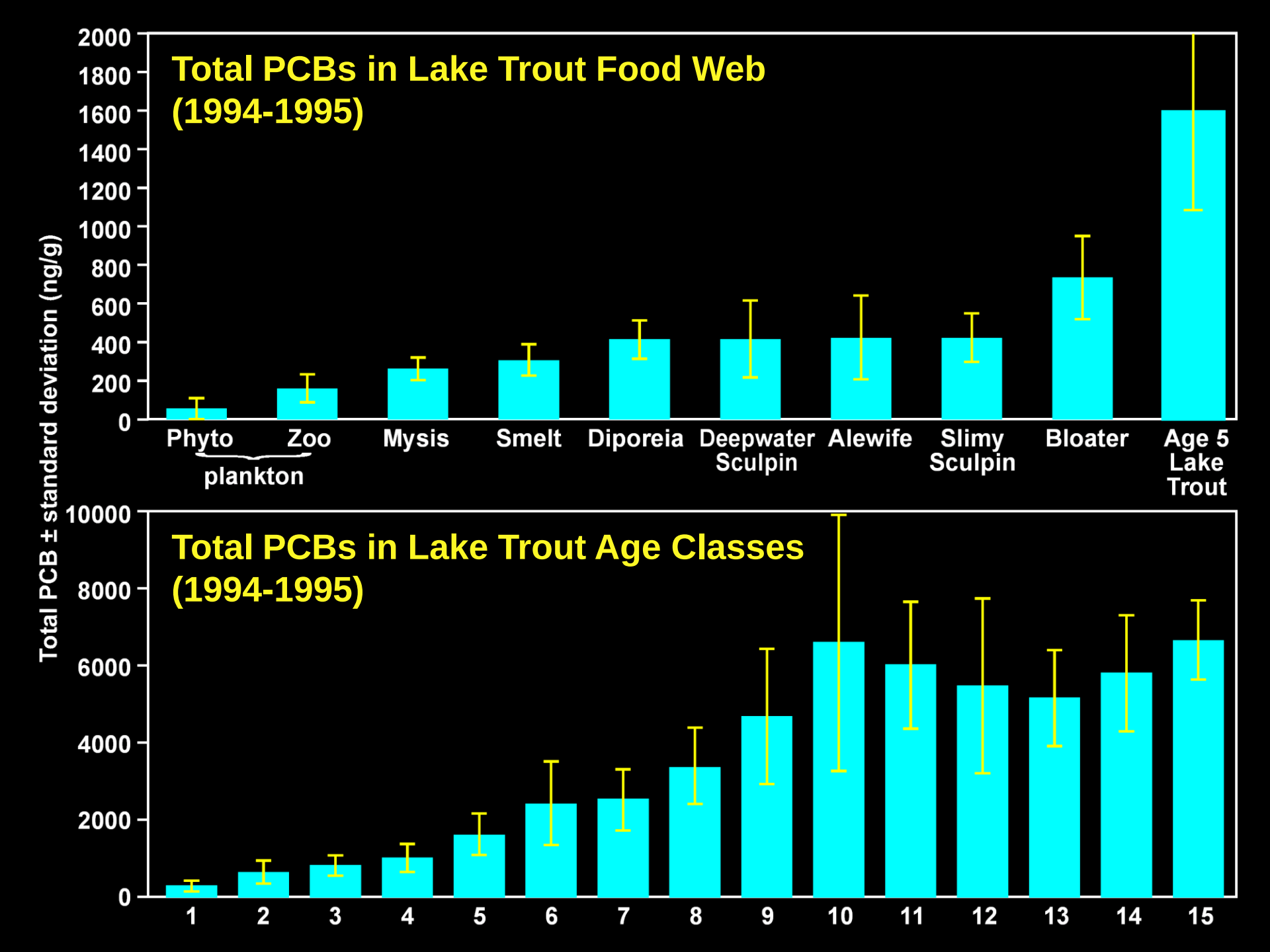

| PCB Inventory - kg | |
|---|---|
| water column | = 1216 |
| active sediment | = 13,085 |
| (0 - 4 cm interval) | |

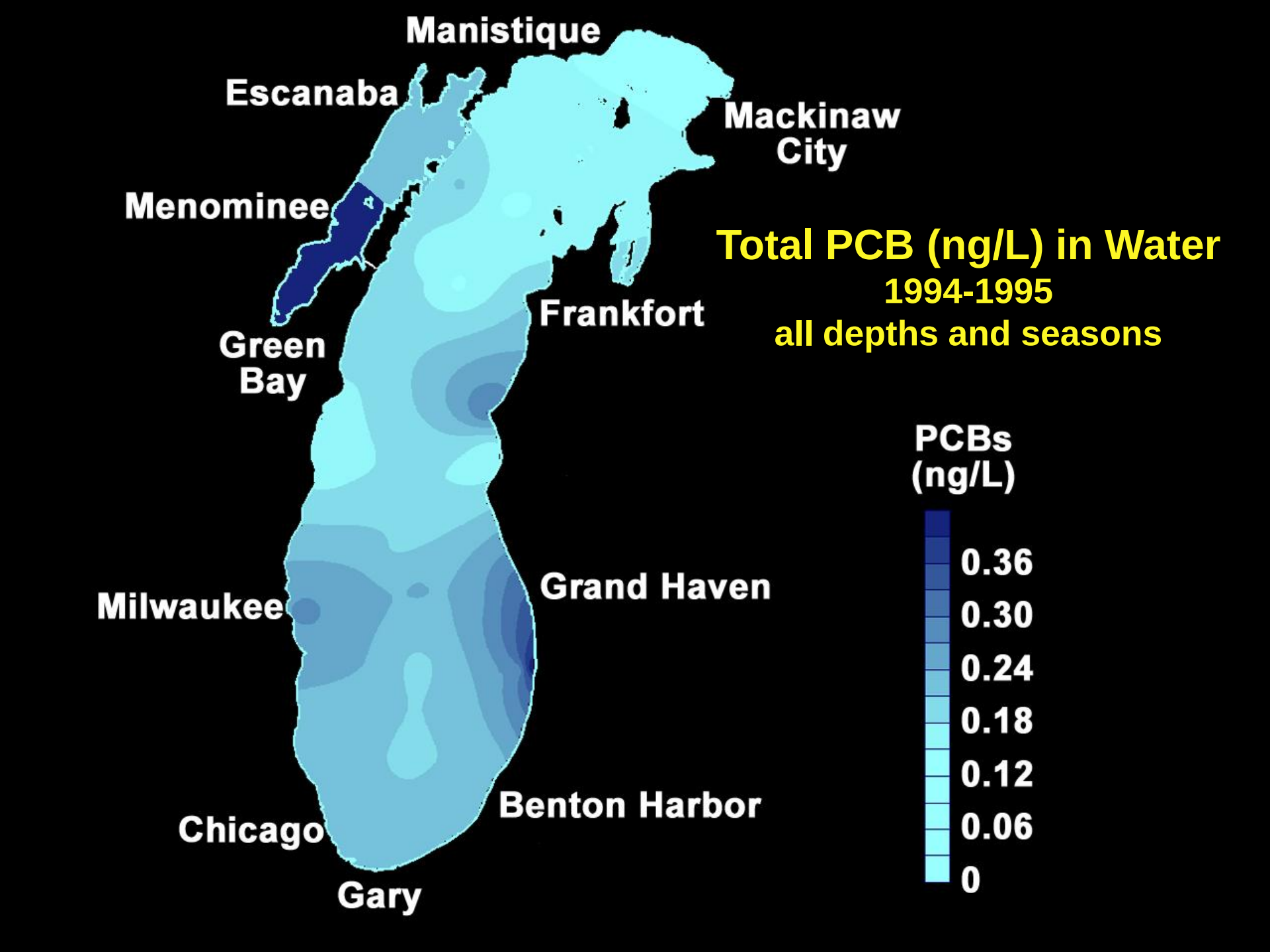
# Median PCB Loading and Concentration Relative to Flow at Lake Michigan Monitored Tributaries 1994-1995

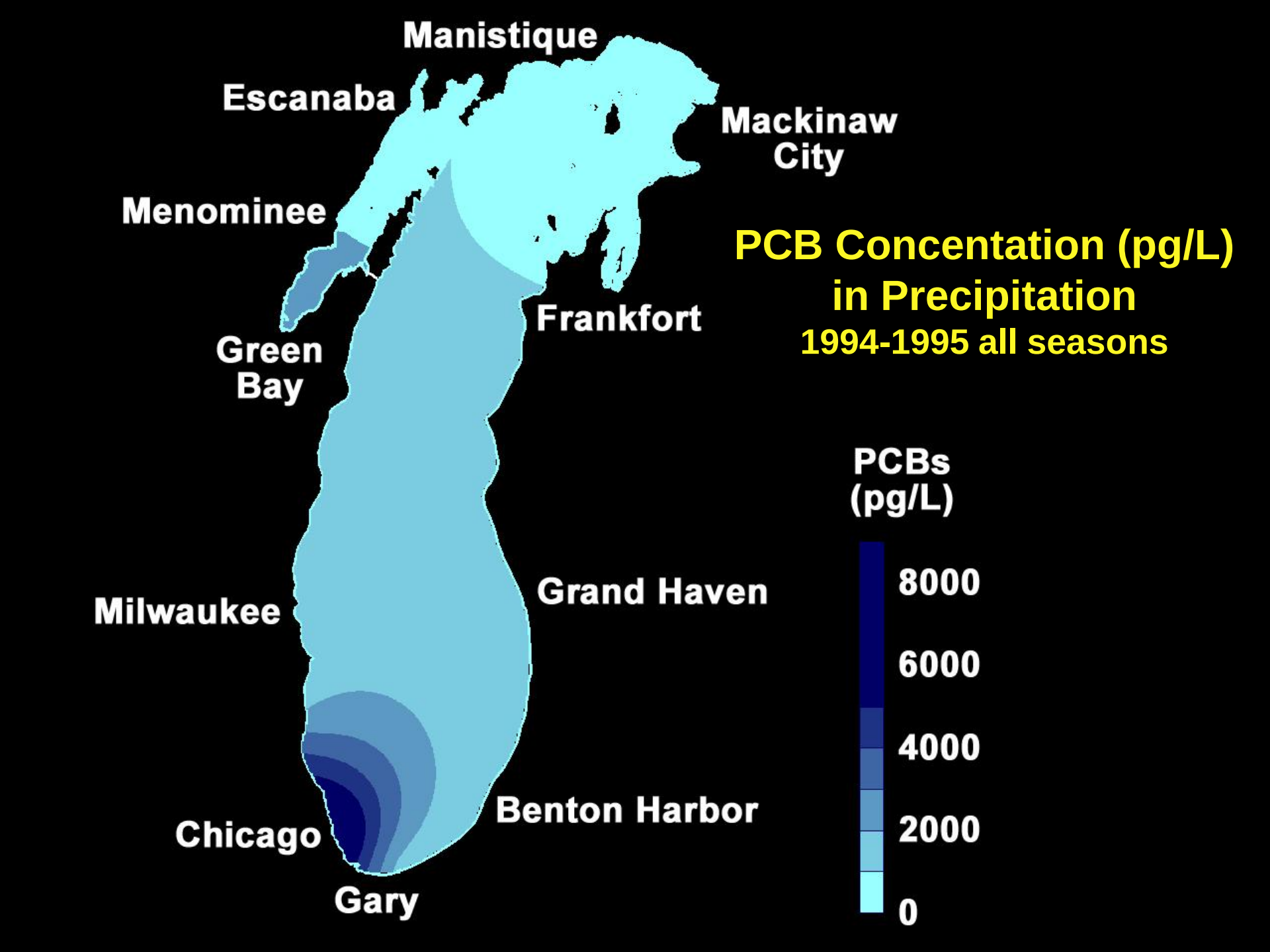


# Predator-Prey Feeding Interactions for Age 5.5 Lake Trout at Saugatuck

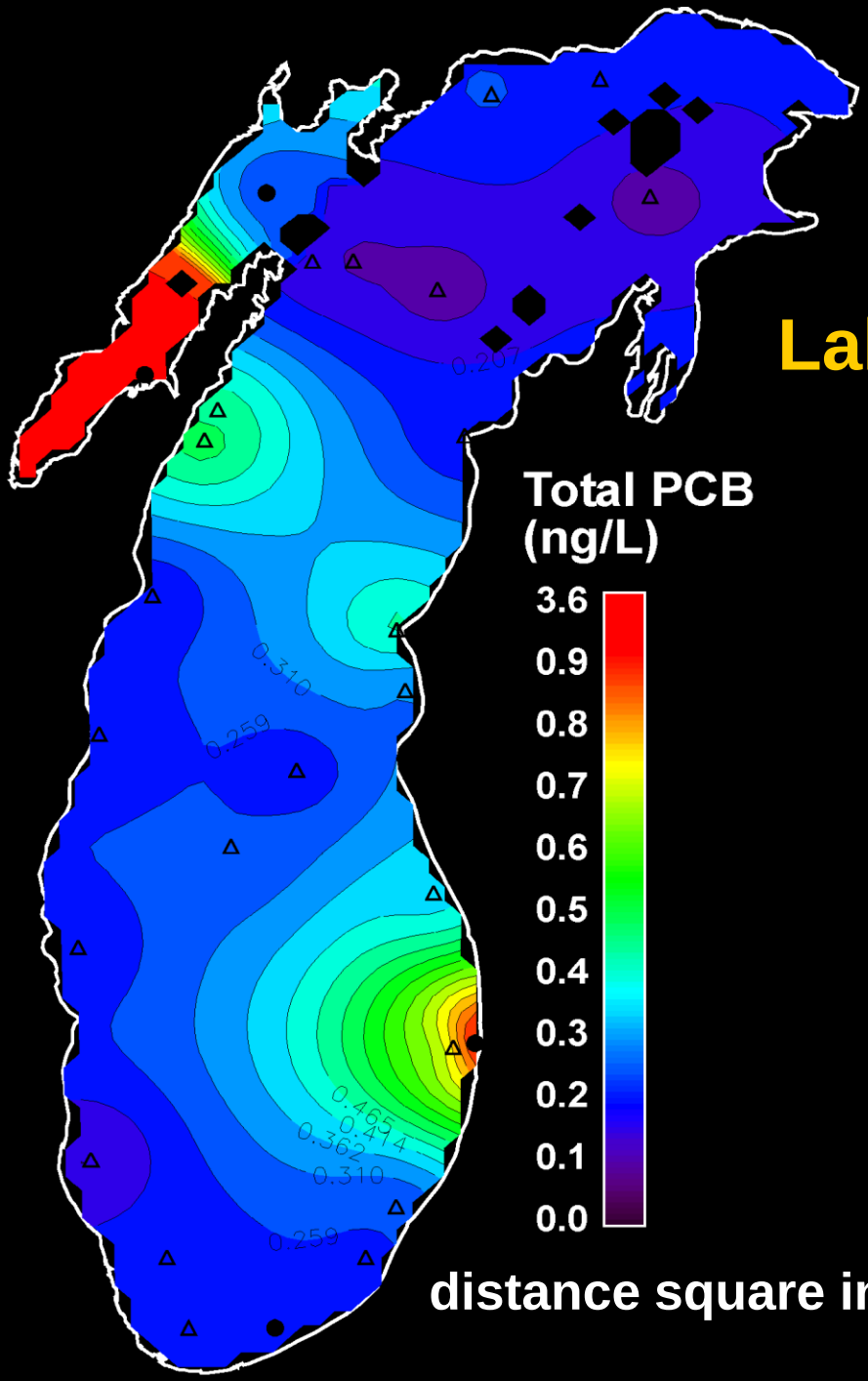



Total PCBs in Lake Trout Food Web
(1994-1995)
Total PCB ± standard deviation (ng/g)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
Phyto
Zoo
plankton
Mysis
Smelt
Diporeia
Deepwater Sculpin
Alewife
Slimy Sculpin
Bloater
Age 5 Lake Trout
Total PCBs in Lake Trout Age Classes
(1994-1995)
10000
8000
6000
4000
2000
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15


Manistique
Escanaba
Mackinaw City
Menominee
Frankfort
Green Bay
Milwaukee
Grand Haven
Benton Harbor
Chicago
Gary
Total PCB (ng/L) in Water
1994-1995
all depths and seasons
PCBs (ng/L)
0.36
0.30
0.24
0.18
0.12
0.06
0


Manistique
Escanaba
Mackinaw City
Menominee
Frankfort
Green Bay
PCB Concentation (pg/L) in Precipitation
1994-1995 all seasons
PCBs (pg/L)
8000
6000
4000
2000
0
Milwaukee
Grand Haven
Benton Harbor
Chicago
Gary

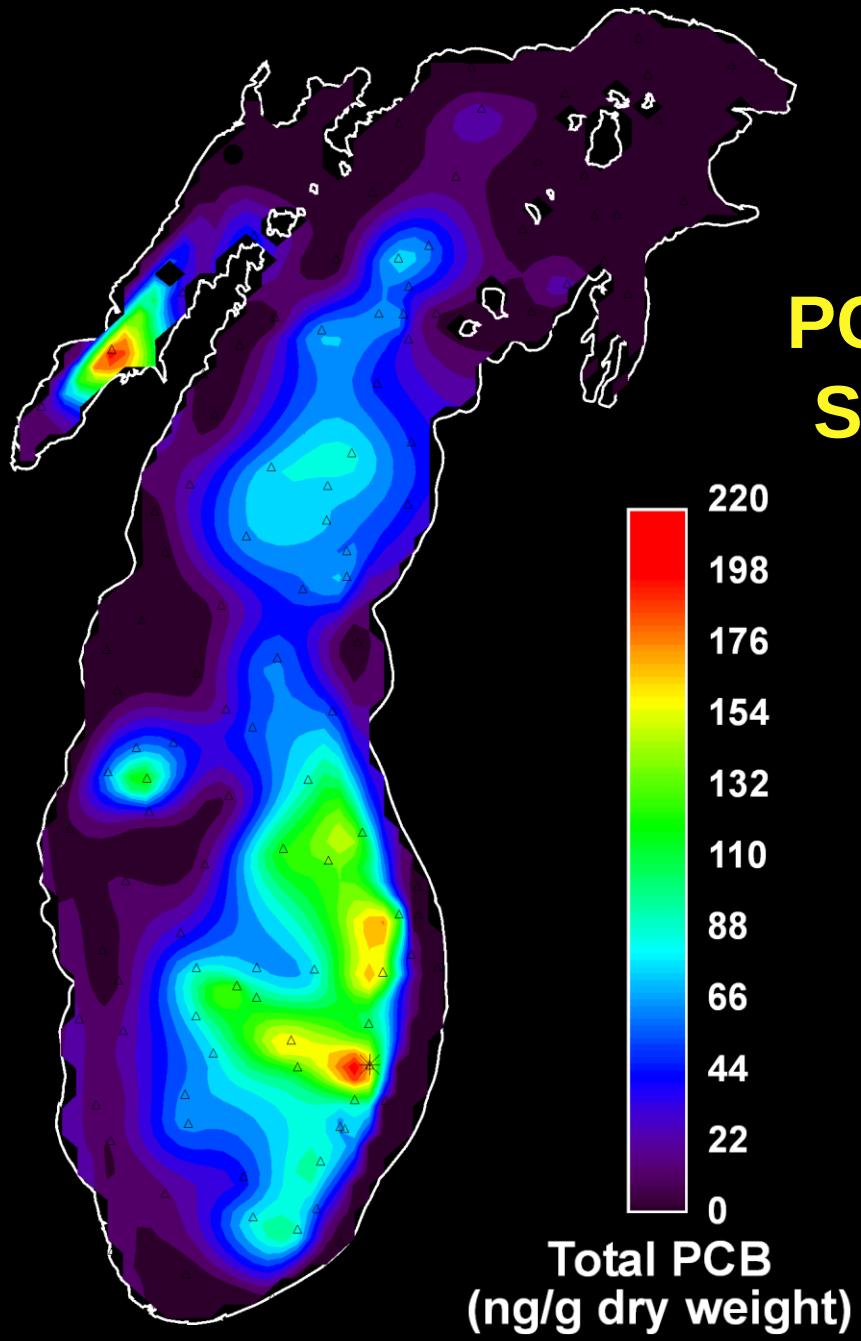
# Concentration of PCBs in Lake Michigan Water 4/24/94 - 5/11/94




Total PCB (ng/L)

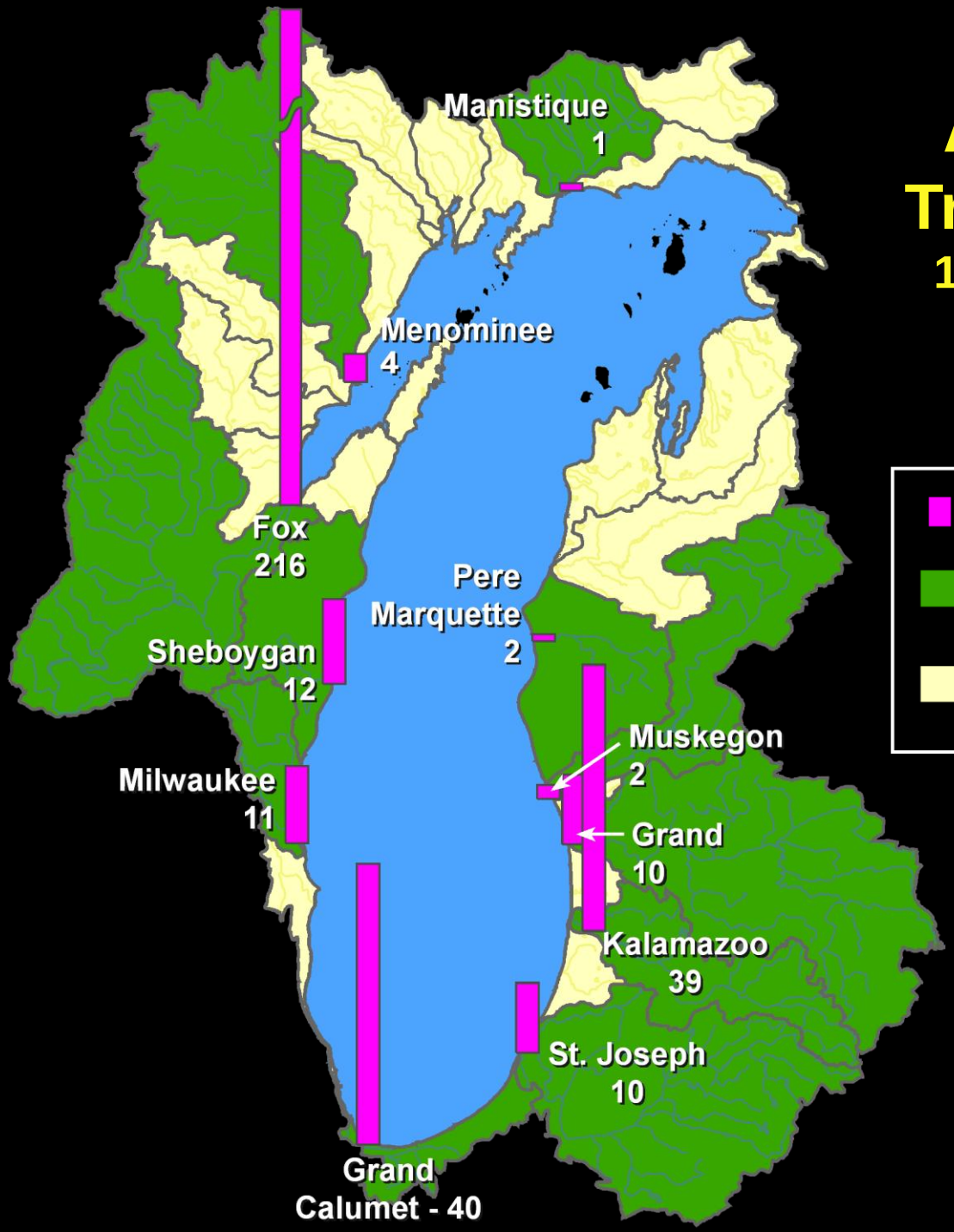
3.6
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0

distance square inverse interpolation




# PCB Concentrations Surface Sediments (1994-1995)

# Average PCB Tributary Loads
## 1994-1995 (kg/year)

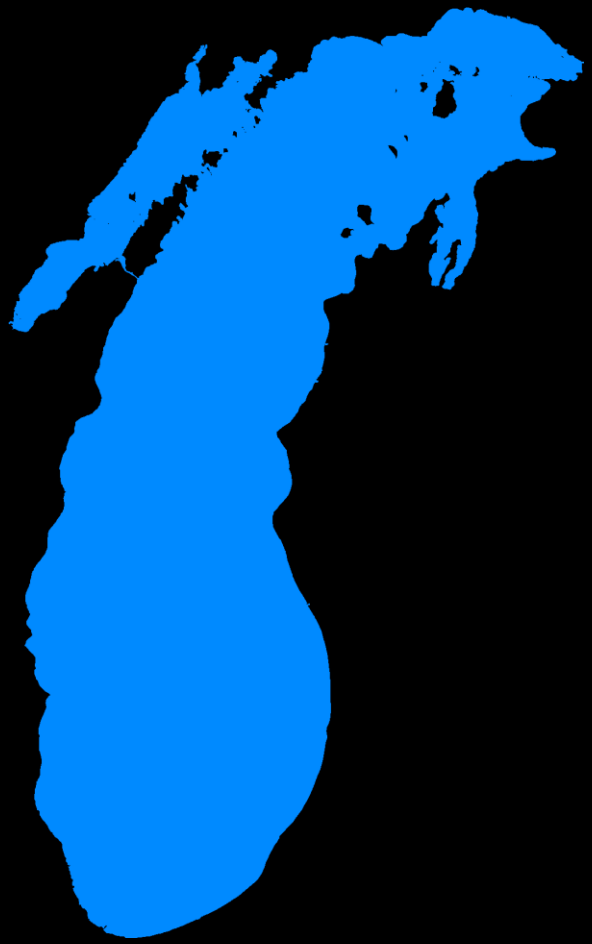



PCB loads (kg/year)

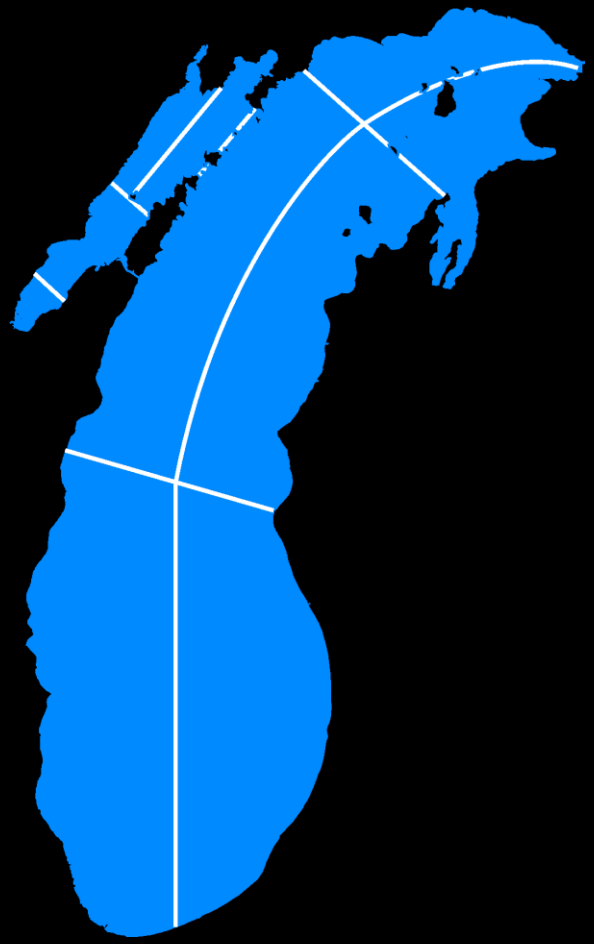
monitored tributary loads: 347 kg/year

unmonitored tributary loads: 31 kg/year

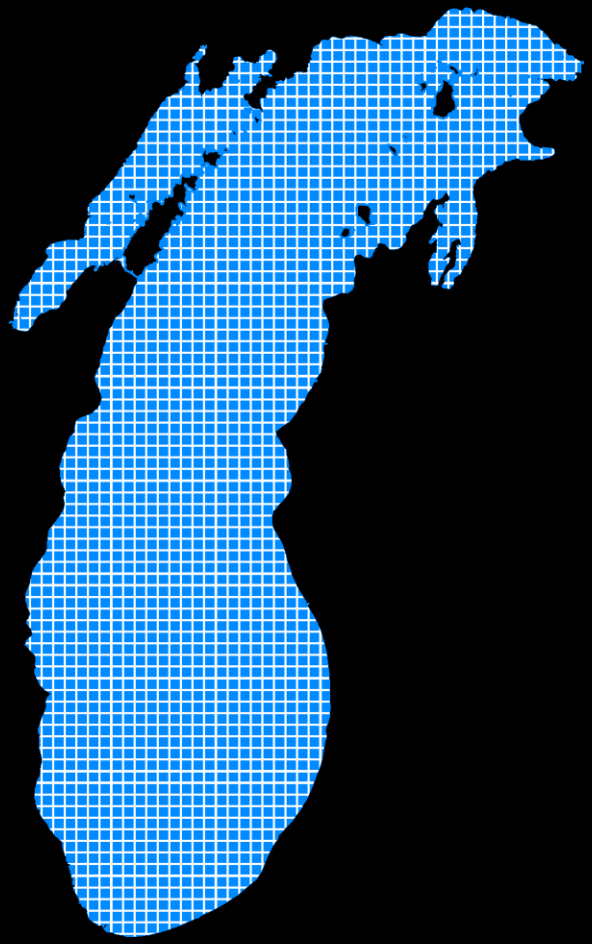
# Lake Michigan Mass Balance Project
# Water Spatial Resolution/Segmentation Scheme



**LEVEL 1**
**Whole Lake**



**LEVEL 2 - LM-2**
**10 Surface Segments**
**41 Water Segments**



**LEVEL 3 - LM-3**
**(High Resolution 5 x 5 km Grid)**
**2,318 Surface Segments**
**44,042 Water Segments**
**19 “Sigma” Levels**

# Lake Michigan PCB Background

**1948 PCBs First Purchased for Use within the Lake Michigan Basin**

**1954-1972 PCBs Discharged to the Lake Michigan Basin**

**1977 PCB Production Banned; Use Continued**

**1989 Remediation of PCB Contaminated Sites Began**

**1991 PCBs Identified as Possible Carcinogen**

**1998 Great Lakes States Developed the "Great Lakes Protocol for Fish Consumption Advisories," Setting a Regional Standard for the Unlimited Consumption of Fillets at 0.05 ppm PCBs**